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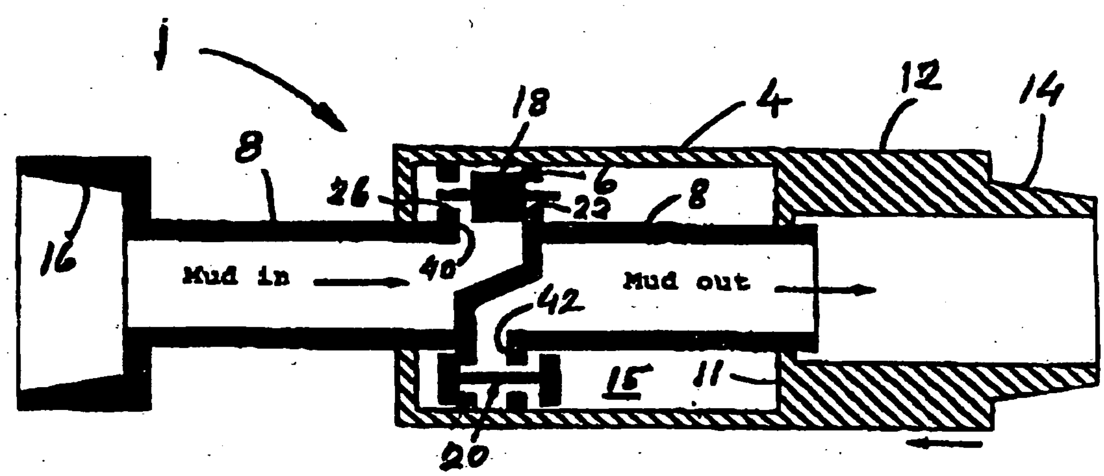

CONTRACTION PHASE

(57) Abstract

The frictional resistance encountered when pushing a pipe string, specifically coiled tubing, into a well bore, is reduced by connecting to the pipe string a device adapted to generate high frequency longitudinal oscillations. The device is in the form of a double acting hydraulic cylinder (1) having automatically shiftable changeover valves (18, 20) through which a fluid such as a well effluent or drilling mud flows via the changeover valves when the pipe string is run into the well bore. The device is also suitable for alternative use as a percussion or setting tool in the pipe string.

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A hydraulic device to be connected in a pipe string.

The present invention relates to a hydraulically operated device adapted to be connected in a pipe string, specifically coiled tubing, e.g. in order to facilitate pushing of the string into highly deviated or horizontal wells in connection with working and maintenance operations such as logging, assembling or disassembling parts, acid and sand washing etc.

It has previously been proposed to provide drill strings with hydraulically operated devices or «vibrators» to facilitate the advance of the string. Thus, US patent 4 384 625 proposes subjecting the drill string to vibrations in the form of resonance oscillations, to reduce the friction between the drill string and bore hole wall in deviated wells to extend the reach in rotary drilling. As an example of a vibrator the patent refers to a fluid operated eccentric weight, implying substantially transversal vibrations.

US patent 3 235 014 describes a method and apparatus for generating axial vibrations through a drilling swivel to transmit a percussive effect to the drill bit.

Furthermore, various types of hydraulic hammer or percussion tools are known, which are intended for loosening sticking drill strings. As an example it is referred to NO patent 171 379.

Coiled tubing has substantially lower mass and diameter than drill pipes, which means that a transversally acting resonance vibrator with accompanying hydraulic motor as proposed in the above US 4 384 625 would be rather ineffective when used in connection with coiled tubing. The main object of the invention, therefore, is to provide a device that effectively reduces friction, both at the coiled tubing head (lowermost tool section) as well as upwardly along the coiled tubing itself.

According to the invention this object is achieved through a device as defined in the appendant claim 1. Advantageous embodiments of the invention are defined in the remaining appendant claims.

A such device mounted to a coiled tubing through which pressurised fluid is flowing will continuously perform telescopic (axial) percussions or vibrations propagating along the entire lower part of the coiled tubing, including the coiled tubing head. The vibrations travel backwards along the coiled tubing and owing to the

steady changes in the direction of transmission of the vibrations, the effective frictional resistance will be drastically reduced and permit the coiled tubing to be pushed a substantial distance into a highly deviated and horizontal well bore before buckling and getting stuck. Calculations based on an 80° deviated well bore indicate an enhanced reach of as much as 3000 m.

The device according to the invention differs from prior vibrators intended for use in petroleum wells, primarily by the fact that it generates a telescopic (axial) vibration at a relatively high amplitude. Existing vibrators as discussed above are primarily designed to provide short and violent percussive pulses during drilling, or for releasing stuck tools. These hammer tools operate at a much lower vibration amplitude, implying vibrations of a substantially shorter operational range. Thus, they are of little use in enhancing the reach of coiled tubing.

Of course, although the primary object of the invention, as discussed above, is to provide a vibrator suitable for reducing the push frictional resistance of coiled tubing, there is nothing to prevent it from being used with advantage also in ordinary rotary drill strings. Furthermore, the purpose of the use of the device need not necessarily be to reduce friction. Thus, in some cases it may be advantageously used as a percussion tool, preferably mounted in front of the pipe string.

The invention will now be described in detail with reference to the drawing, in which figures 1 - 3 are schematic longitudinal cross sectional views showing the device according to the invention and its operation in three different phases.

The device according to the invention builds on per se well-known technology. Thus, in principle it is in the form of a double acting hydraulic cylinder having automatically operated changeover valves. As shown in the figures it comprises a hydraulic cylinder 1 including a cylinder barrel 4 and piston 6 having a tubular double piston rod 8 extending through the barrel end walls 10, 11 respectively. One end of the cylinder barrel has a tubular extension 12 receiving and preferably extending axially somewhat beyond the part of the piston rod 8 therein when the latter is in its outer end position (fig. 2). The extension 12 terminates in a threaded portion 14 formed to mate with a corresponding threaded portion of a member of a pipe string such as coiled tubing. Similarly, the piston rod end protruding at the opposite end of the cylinder barrel also terminates in a threaded portion 16 adap-

ted to mate with a pipe string member. In the drawings the threaded portion 14, 16 are shown as being tapered, but they may just as well be cylindrical, as is now most usual for coiled tubing. In the example shown the cylinder end portion 14 has external threads and the piston rod end portion 16 internal threads. However, the arrangement may of course be reversed if desirable. The cylinder 1, in its embodiment as shown, is designed to be mounted to the pipe string with its cylinder threaded portion 14 facing «forward», i.e. in the direction of advance of the pipe string. Consequently, in what follows, phrases such as forwards, backwards, foremost, rearmost, front, rear, refer to the direction of advance of the pipe string (from left to right on the drawing).

The piston 6, which divides the cylinder barrel 4 into front and rear cylinder chambers or annulus 15 and 17 respectively, supports a plurality, in the shown example two, shuttle valves in the form of valve members 18 and 20 adapted to be axially displaced between a front port, 22 and 24 respectively, and a rear port, 26 and 28 respectively, formed in the piston faces 23, 25 and opening into front annulus 15 and rear annulus 17, respectively. Shifting of the shuttle valves is automatically brought about by mechanical actuation whenever the piston reaches an end position. The two shuttle valves 18, 20 act as an inlet valve and outlet valve respectively, as explained in more detail below.

A lateral partition 34 divides the interior of the tubular piston rod into a rear part or inlet passage 36 and a front part or outlet passage 38 which, via an inlet opening 40 behind the partition and an outlet opening 42 in front of the partition, communicates with the inlet valve 18 and outlet valve 20, respectively.

In operation, with cylinder 1 mounted and oriented in a pipe string as described above, the device according to the invention will perform successive contraction and expansion phases, activated by fluid, such as drilling mud, pumped through the pipe string.

In fig. 1 the device is shown at the start of the contraction phase or stroke. Pressurised fluid flows into and through inlet passage 36, inlet opening 40, the open rear inlet port 26 and out into the rear cylinder annulus 17. The fluid pressure in the rear annulus urges the piston forward relative to the cylinder barrel, while the inlet and outlet valve members 18, 20, urged by the fluid pressure, close

the front inlet port 22 and rear outlet port 28 respectively, to prevent fluid from flowing into the front cylinder annulus 15, and fluid in the front annulus flow through the open outlet port 24, through outlet opening 42, into piston rod outlet passage 38 and thence further to pipe string members downstream.

Fig. 2 shows the cylinder at the end of the contraction phase, when the two shuttle valves 18, 20 automatically shift as they encounter the front end wall 10 pushing them backwards to open front inlet port 22 and rear outlet port 28. This causes the pressurised fluid to flow via port 22 into front annulus 15 to fill the latter, while the fluid in rear annulus 17 flows out through rear outlet port 28 and opening 42, outlet passage 38 and further through the pipe string. At this point the inlet and outlet valve members 18, 20 will be urged by the fluid pressure in the front annulus to close the rear inlet port and front outlet port respectively as shown in fig. 3 to start the expansion phase in which the piston, urged by the fluid pressure in the front annulus, moves backwards relatively to the cylinder barrel, until the valve members again shift as they encounter the rear end wall 11 of the cylinder barrel and a new contraction stroke starts as described above.

When the device is to act as a friction reducing vibrator in a coiled tubing, it is normally positioned in between the coiled tubing and tool string. In order to produce an optimal friction-reducing effect the vibrations must have a certain amplitude (typical stroke: 10 - 50 mm) and a frequency high enough (typically 2 - 15 cycles per second) to permit the inertia of the tool string to force a considerable amount of the vibrations upwards along the coiled tubing. If a long stroke were to be chosen and a correspondingly low frequency, then the device would exhibit a functional mechanism different from that described above, since in that case the tool string would reciprocate. During the contraction phase the tool string would serve as a frictional anchor, with the device pulling the string after itself.

The vibration frequency is determined by the cylinder volume, stroke and flow rate. On the other hand, with a given cylinder volume and stroke, the flow rate is determined by the fluid pressure and by the effective opening areas of the valves 18, 20. Although only two shuttle valves are shown in the schematic drawing, i.e. one inlet valve 18 and one outlet valve 20, in order to minimise the pressure loss across each valve normally a plurality of valves, e.g. six valves, would

be needed, i.e. three sets alternately distributed as inlet valves 18 and outlet valves 20. Furthermore it should be noted that although the piston partition 34 is schematically shown as a solid or unbroken inclined wall, if desirable it could be adapted to accommodate various valves. For example, pressure relief valves and/or flow control valves could be installed, closing when the flow rate exceeds a certain level.

As previously mentioned, the above described example of an embodiment of the vibrator device according to the invention is schematically illustrated in the drawing, since it builds on per se well-known technical details which a person skilled in the art without difficulty would be able to implement in a suitable manner. Specifically, in practise the shuttle valves are conceivable in many forms.

However, in order not to leave any doubt as to the practical feasibility of the device, the example as shown in the drawing will now be described in a somewhat more detailed manner. Thus, in the drawing the inlet valve 18 is indicated as a cylindrical body slidably supported in inlet ports 22, 26 via two pins or shafts 19 (fig. 3) axially protruding from either side of the valve member. In the schematic figures which primarily are meant to illustrate the principle of the design and operation of the vibrator according to the invention, these shafts 19 are indicated as «floating» in ports 22, 26. In practice they would of course be sized to have a sliding fit diameter. Further, they would be formed in a manner to permit fluid to flow freely through an open inlet port. Thus, the shafts 19 could be in the form of perforated pipes, or a perforated bearing sleeve could be mounted in the ports. The distance between the outer ends of the shafts 19 is slightly larger than the distance between the faces of the piston 6, to cause shifting of the valve when the outer ends of the shaft encounter end walls 10, 11 of the cylinder barrel.

The outlet valve 20 is shown as a disk-like body at each end of an intermediate shaft 21 extending through outlet ports 24, 28 and acting as a support for the outlet valve body, in the same manner as described above in connection with the inlet valve member, and the distance between the outer ends of the disks 21 is substantially equal to that between the end surfaces of the inlet valve shafts, i.e. somewhat larger than the distance between the piston faces, in order to bring about shifting of the valve upon encountering the cylinder end walls 10, 11. The

valve members 18, 20 could of course be spherical rather than disk-like. Furthermore, for optimal performance, some kind of spring means could be provided to accelerate the valve shifting and/or to hold the valve more steady at the end positions. It would not be necessary to explain these and other details of the valve structure in further details, since a person skilled in the art would realise what is needed to obtain a satisfactory valve performance.

As to the main dimensions of the cylinder barrel 4, its outer diameter would normally be equal to or less than the outer diameter of the pipe string to which it is connected, while the length of the cylinder barrel would depend on the desired stroke of the cylinder 1.

When using the vibrator device according to the invention in connection with coiled tubing operations, the device, as noted above, will normally be connected in between the coiled tubing and the tool string. However, as introductorily mentioned, the device according to the invention is also contemplated as a percussion tool mounted in front of the pipe string, and then possibly with a shape different from the front end threaded portion 14.

Although the cylinder 1 of the example as shown and described is adapted to be connected to the pipe string with its cylinder end portion 14 facing forward, which means that the fluid would flow in direction from left to right in the figures, it could just as well be designed for «reversed» connection, which means that the fluid would flow from right to left, since then the two shuttle valves 18, 20 are interchanged relative to the piston rod partition 34.

Patent Claims:

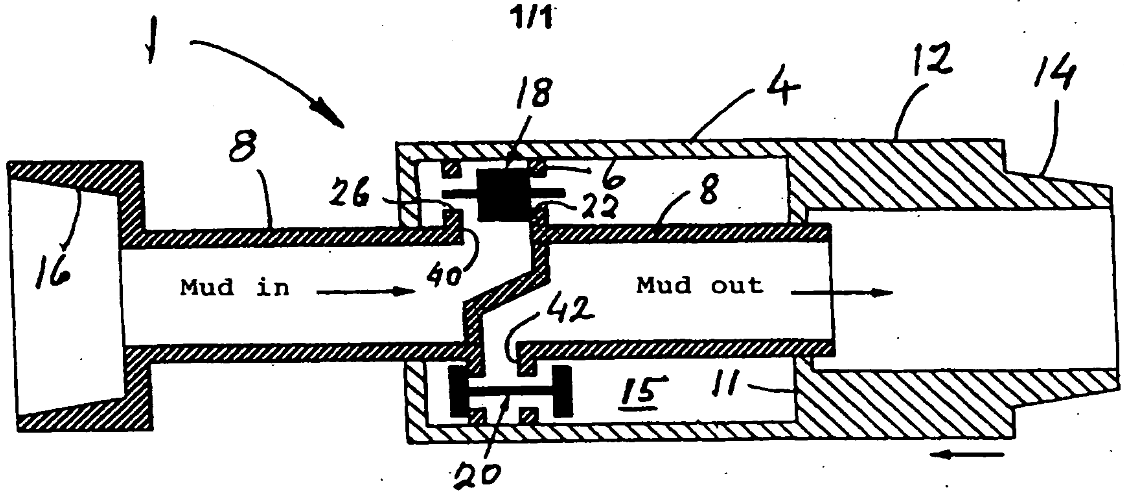
1. A device adapted to be connected in a pipe string, specifically coiled tubing, for generating vibrations or percussions therein when pumping a fluid, e.g. drilling mud, through the pipe string, characterised by being in the form of a double acting hydraulic cylinder (1) having automatically shiftable changeover valves (18, 20), said cylinder comprising a cylinder barrel (4), a piston (6) dividing the cylinder barrel into two separate chambers (15, 17), and a double tubular piston rod (8) through which said fluid, during operation of the device, will flow via the changeover valves (18, 20) and cylinder chambers (15, 17), said cylinder (1), at least at one end, being formed with a threaded portion (14, 16) for connection to the pipe string.

2. A device according to claim 1, characterised by said changeover valves (18, 20) being two shuttle valves disposed in the piston (6) on either side of a lateral partition (34) that divides the interior of the piston rod into two separate spaces, each of which communicates with a respective shuttle valve (18, 20) to define an inlet passage (36) and an outlet passage (38) respectively for the fluid flowing via the shuttle valves into and out of the cylinder chambers (15, 17).

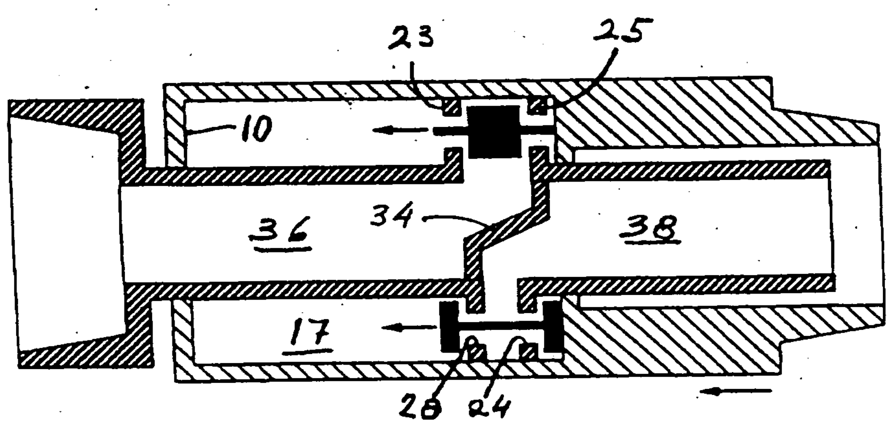
3. A device according to claim 2, characterised by the shuttle valves (18, 20) being arranged for mechanical shifting.

4. A device according to claim 3, characterised by each of said shuttle valves (18, 20) being in the form of a valve member axially slidably supported via shafts (19, 21) in two valve ports (22, 26 and 24, 28 respectively) formed in the piston end walls (23, 25) and opening into a respective cylinder chamber (15, 17), said shuttle valves being adapted to be shifted upon encountering the cylinder end walls (10, 11).

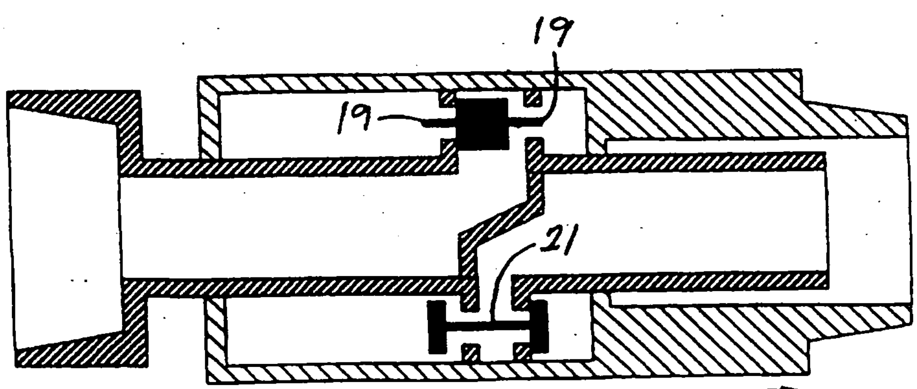
5. A device according to any one preceding claim, c h a r a c t e r i s e d b y the stroke of the piston (6) being in the range of 10 - 50 mm and the stroke frequency being in the range of 2 - 5 cycles per second.



CONTRACTION PHASE FIG. 1



SHIFTING: CONTRACTION - EXPANSION FIG. 2



EXPANSION PHASE FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 97/00146

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: E21B 7/24, E21B 4/14, E21B 28/00
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 3225014 A (W.B. BROOKS), 15 February 1966 (15.02.66), column 3, line 17 - line 32 -- --------	1

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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